COMPARING THE TIME COURSES OF TOP-DOWN AND BOTTOM-UP ATTENTION IN THE TEMPORAL DOMAIN

A Senior Honors Thesis

Presented to

the Faculty of the Department of Psychology

University of Houston

In Partial Fulfillment

of the Requirements for the Degree

Bachelor of Arts

By

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December, 2019

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Abstract

Attention shifts within and between time and space frequently during our everyday life. Attention can be controlled both voluntarily and involuntarily and the brain must choose which stimuli are most relevant to process. It is known that this shift in attentional control is costly for the brain in terms of time and resources. In comparison to the well-studied spatial attention, the time courses of top-down (voluntary) and bottom-up (involuntary) temporal attention are less well-known. We examined both top-down and bottom-up attention using the attentional blink and emotion-induced blindness paradigms respectively in order to better understand whether the hallmarks of top-down/bottom-up distinctions in spatial attentional control also occur in temporal attentional control. Participants searched rapid serial visual presentation streams for either two targets or one target following an emotional distractor image. The results showed that participants demonstrated an AB effect, but most likely failed to notice the emotional distractor images and therefore did not show an EIB effect. Due to the lack of the AB-like effect in the EIB condition, this study remains inconclusive as the data in the bottom-up attentional control (EIB) condition were not interpretable.

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Introduction

When talking to a friend at a noisy restaurant, you focus on your friend rather than on the extraneous noise. However, if there was a loud bang, you would probably turn to see what happened. Unexpected, salient events take priority over other events in terms of processing in the brain (Corbetta & Schulman, 2002). This is an example of selective attention, or the process by which the brain selects some stimuli to be fully processed. When the brain is flooded with sensory stimuli, it picks out one or a few of the most relevant stimuli to attend to and suppresses things and events that are deemed as irrelevant (Serences et al., 2005). By selecting the most relevant information to process, we can respond to the environment in a more efficient manner. Attention shifts from stimulus to stimulus in our everyday lives and we sometimes do not consciously control or choose which stimuli we choose to attend to. Just as we must attend to items in a specific location/space, we must also attend to relevant moments in time, which is known as temporal attention. Shifting between where or when attention is focused is costly for the brain in terms of both resources and time, as shifting between items can only occur so quickly (Corbetta & Schulman, 2002). This attentional shift can be studied for both spatial and temporal attention using paradigms such as the attentional blink (AB) and emotion-induced blindness tasks (both of which will be discussed later), which can incorporate both top-down (goal-driven—e.g., in the example above, choosing to focus on your friend) and bottom-up (stimulus-driven, e.g., in the example above, having your attention "captured" by the loud bang) attentional control. However, we do not know how similar or different attentional control mechanisms are for temporal versus spatial attention. One way to understand this is to examine the time courses for top-down versus bottom-up attention, similar to the study done by Muller &

Rabbitt (1989), in which they investigated the mechanisms that underly covert orienting of attention in visual space. Investigating whether the hallmarks of top-down/bottom-up distinction in the better-studied spatial attentional control similarly occur in temporal attentional control is important to understand more about temporal attention and the ways in which it works.

Top-Down and Bottom-up Attention

In the cognitive psychology literature, attention is categorized into two types: bottom-up and top-down. Top-down, or goal-oriented, attention refers to perception that is driven by cognition. In other words, this refers to attentional control in which the subject purposely and voluntarily directs their attention (Egeth and Yantis, 1997). Top-down attention is also called endogenous or sustained attention because it is clear voluntary control and attention is focused on a particular object, event, or region for a sustained period of time (Pinto et al., 2013). However, attention is not always voluntarily directed. Bottom-up, or stimulus-driven attention, refers to the processing of sensory information as it comes in. This occurs when salient stimuli draw attention even when someone had no intention of attending to said stimuli. Two common properties for stimuli that capture attention in spite of being goal-irrelevant are stimuli that are considerably different from surrounding stimuli and abrupt visual onsets (Egeth and Yantis, 1997). Bottom-up attention is also known as exogenous or transient attention because unlike the voluntary nature of top-down attention, bottom-up attention is involuntary (Pinto et al., 2013). Past research also suggests that top-down and bottom-up attention come from two independent attentional control systems and compete for preferential processing of stimuli (Ligeza, Tymorek and Wyczesk, 2017). According to Wolfe's (1994) Guided Search model, attention is directed in order of priority. Attentional priority is determined by top-down activation, or how closely an item is related to the current task goals, and bottom-up activation, or how different other stimuli are from the from the task-related stimuli or the entire set of stimuli, and whether or not they are salient enough to capture attention (Egeth and Yantis, 1997). For example, if the participant's task is to identify a green object amongst red objects the green object will be much more salient than if it was amongst blue objects because of green and blue are more similar to one another than green and red. Interestingly, previous research on top-down and bottom-up attention has shown a fast but transient effect for bottom-up attention, and a slow but durable effect for top-down attention, with top-down attention taking about 300 ms compared to the 100-120ms for bottom-up attention (Pinto et al, 2013, Muller & Rabbitt, 1989). However, it has been shown that shifts of attention involve several operations which include disengaging from the current target, shifting attention and then maintaining a new locus of attention (Serences, Liu, and Yantis, 2005).

Attentional Blink

The distinction between top-down and bottom-up attention has been studied in the domain of temporal attention using paradigms such as the Attentional Blink (AB). In the AB, participants are asked to identify two targets (T1 and T2) among a series of other items and have been shown to have difficulty correctly identifying T2 when it appears in close temporal proximity to T1. For example, if you are on your phone and multiple notifications pop up one after another, you might have a hard time remembering the second notification because you are focused on the first one (as long as the second one is presented only briefly as well). Studies that examine the AB most often use variations of the rapid serial visual presentation (RSVP) task, in which stimuli are presented one at a time in the same spatial location in rapid succession at a rate of about 100 milliseconds per item. In the classic AB paradigm (Figure 1A), two distinct targets items are embedded among a stream of distractors and the temporal distance (lag) between the two targets is manipulated (Raymond, Shapiro, & Arnell, 1992). Participants are to complete a goal-oriented task in which they are instructed to identify specific targets in a stream of non-target distractors. Commonly used targets are letters (e.g., detect the letter X amongst a stream of numbers), color-specific items (e.g., identify the green letter in a stream of white letters) and images (e.g., identify a teapot amongst other images). Between the two targets are a variable amount of inter-target distractor items, used to examine the differences in target recollection as a function of T1 to T2 lag. The AB occurs when the ability to accurately report the second target (T2) is impaired when it is close in temporal proximity to the first target (T1). Specifically, this effect is maximal when there is a single distractor stimulus separating the two targets (lag 2 from T1), and diminishes over time/lags, suggesting that the AB lasts approximately 200-500 ms (Raymond, Shapiro, & Arnell, 1992). In terms of lags, the AB exists between Lags 2 and 6, before performance levels off (Figure 1B for typical AB data).

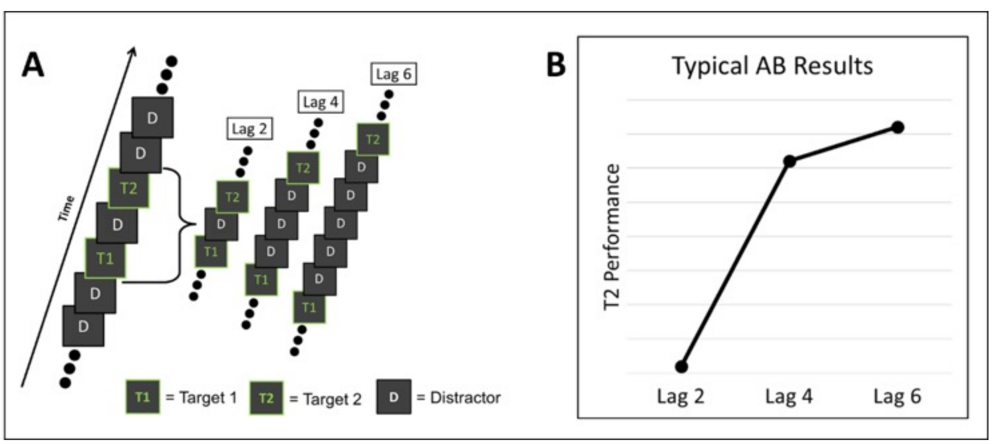

Figure 1. An example of the classic two-target AB RSVP paradigm (A) Lags represent the temporal distance from T1 to T2. Lag 2 has one inter-target distractor (approximately 240 ms from T1 onset to T2 onset) and yields poor performance on T2 recollection—an AB effect. Lag 4 has three inter-target distractor (approximately 480 ms) and

shows very little AB effect on T2 recollection. Lag 6 has five inter-target distractors (approximately 720 ms) and shows almost no AB effect on T2 performance. A cartoon illustration of typical AB data. Performance is measured by the percentage of correct T2 answers when T1 was also correctly reported. (B).

The AB phenomenon has been thought to be the result of the two targets competing for limited attentional resources (Chun & Potter, 1995; Jolicœur & Dell' Acqua, 1998). Raymond et al. (1992) found that when T1 was correctly reported, the ability to report T2 was impaired if T2 appeared between 200 ms and 500 ms of T1 (Dux and Marois, 2008). With this framework, one would expect performance to be worst when T2 directly follows T1, however it was found that there was little to no deficit in T2 accuracy when it appeared directly after T1, a phenomenon known as Lag 1 sparing (Dux and Marois, 2008). Additionally, T2 performance strongly improved when there was a gap or a blank between T1 and T2, which suggests that the stimuli that follow T1 play an important role in the ability to detect T2 and thus the AB effect (Dux and Marois, 2008). There are several theories as to why the AB occurs. Raymond et al.'s (1992) gating theory proposed that an attentional episode is triggered after the detecting of the first target. This "gate" opens for a limited time and closes until it fully processes T1 but is open long enough to process T1 as well as the stimulus that follows T1. This explains Lag 1 sparing as well, because T2 appears directly after T1 and Lag 1 sparing is dependent on an inter-target distractor (Dux and Marois, 2008).

Emotion-Induced Blindness

In a variant of the classic AB paradigm, emotionally arousing words or images (e.g. an image of a snake poised to strike) replace T1 in the stream of images. Participants are instructed to identify a single target (here referred to as T2, because it occupies the same ordinal positions in the RSVP stream as T2 in the AB condition), which appears after the emotional item. This is known as emotion-induced blindness (EIB), where emotionally arousing stimuli impair the ability to detect items presented a short time after (Kennedy et al., 2014). The critical distractor item (CDI) that replaces T1 leads to an AB-like “emotional attentional blink” or “emotion-induced blindness” (Most et al., 2005). In the EIB, T2 is affected by the task-irrelevant CDI similarly to how it is affected by T1 in a typical AB study. Participants are told to look for only one target (T2) which appears in the same temporal location as T2 in the classic AB study. The emotional CDI appears in place of T1 and thus, the emotional critical CDIs are shown to capture attention, reflecting involuntary (“bottom-up”) attentional biases towards emotionally arousing stimuli. Though participants are engaged in a goal-driven task, they are still distracted by these emotional stimuli. Kennedy and Most’s (2015) study, in which they compared the effects of emotional distractor images in categorically homogenous (e.g., all teapots) and categorically heterogenous (i.e., each image from different object/scene categories) RSVP streams, found that emotional stimuli’s robust effect on attention occurred and disrupted target perception regardless of the categorical distinctiveness. A study by Mathewson et al (2008) found similar patterns of reduced accuracy in reporting of T2 when taboo (sexual and curse) words were used as T1 in classic AB tasks and when the same emotionally arousing words were used as distractors in EIB tasks. Mathewson et al. (2008) used the same words in the two tasks (AB, EIB) and used a correlational analysis to show that the words that reduced T2 accuracy when presented as T1 in an AB task were highly similar to the words that reduced target accuracy when presented as to-be-ignored distractor words in the EIB task. This suggests that emotional/taboo words have preferential processing at the expense of identifying subsequent targets. A possible explanation for why the EIB occurs is that attention can be captured on the basis of the affective value of a stimulus as well as categorical distinctiveness (Kennedy and Most, 2015). In most emotion-induced blindness studies, the emotional distractor is categorically different from the rest of the RSVP stream (e.g. an animal amongst a stream of teapots), and thus has both an emotional as well as a categorically salient effect.

Current Study

In the present study, the goal was to understand the relationship between the time-courses of both the classic AB and EIB within individual participants. This is important because it is unknown if top-down control (AB) and bottom-up control (EIB) over temporal attention are really comparable to top-down and bottom-up attentional control, respectively, in the better-studied domain of space or items. Previous research on top-down and bottom-up attention using spatial cuing paradigms has shown a fast but transient effect for bottom-up attention, and a slow but durable effect for top-down attention (e.g., Muller & Rabbitt, 1989). However, Muller & Rabbitt (1989) and other studies comparing the time course of top-down and bottom-up attention have relied on cuing of visuospatial selective attention. It is unclear if the same differentiation of time courses between top-down and bottom-up attention should be expected for temporal attention. If the same differentiation of time courses is observed, it would be consistent with shared attentional control processes for visuospatial attention to locations/objects and temporal attention to moments in time/RSVP items. Based on the information we have about spatial attention, we hypothesize that the EIB (bottom-up) condition will have a more transient blink or in other words, will have a faster and short blink span than the AB condition.

Methods

Participants

Data for this experiment were collected at the University of Houston. The participant pool consisted of students receiving course credit for participating via SONA. The experiment had 8 participants (4 females; mean age = 21, SD= 3.82). Participants were at least 18 years of age, able to perform the basic requirements of the task, did not self-report a history of neurological disorder, injury, or major psychological disorder known to affect cognitive capacity limits, did not self-report a history of vision problems (other than wearing corrective lenses), and did not self-report using psychoactive medications or drugs. Informed consent was collected from all participants.

Procedure

All procedures were approved by the Institutional Review Board of the University of Houston. The current study used a variation of the classic two-target AB RSVP paradigm and the classic one-target EIB paradigm. Participants were given both verbal and on-screen instructions to attend to the images outlined in green among a stream of images outlined in other colors. Participants began each trial by pressing the spacebar. There were two types of trials: those with two targets and neutral CDIs (Classic AB) or trials with one target and an unpleasant CDI replacing target 1 (EIB). There were 210 AB trials and 210 EIB trials for a total of 420 trials. The AB and EIB conditions were intermixed so that they occur in a random order within the 420 trials. In the classic AB condition, each trial began with 3-6 pre-target distractor images (randomized, uniform distribution) followed by T1, and an inter-target interval consisting of either 0 (Lag 1, 0ms), 1 (Lag 2, 120ms), 2 (Lag 3, 240ms), 3 (Lag 4, 360ms), 5 (Lag 6, 600ms), 7 (Lag 8, 840ms) or 9 (Lag 10, 960 ms) distractor images (randomized, uniform distribution). This sequence was followed by T2, and finally 4-16 post-target distractor images, with the number of trailing distractors specified by the preceding randomized selections such that the total number of stream items was 21. In the EIB condition, each trial began with 3-6 pre-target distractor images (randomized) followed by an emotional CDI (instead of T1), an inter-target interval consisting of between 0 and 9 distractor images (Lags 1-10), T2, and finally 4-16 post-target distractor images. Thus, the EIB condition was identical to the AB condition except that it had only one target that the participant needed to identify instead of 2 for the AB condition. Each of the 21 images in the stream were shown in the center of the screen for 120 ms in duration for all experimental conditions. Following the stream, participants reported the targets they observed via a probe display similar to the one used by Kennedy and Most (2015). Specifically, participants used a mouse to select the targets from an array of 20 of the images from the stream (excluding the emotional CDI from the EIB trials, and the third image from the AB trials) and participants were prompted to select the one or two target items that had been outlined in green during the RSVP stream. During the probe display, no colored frames were presented around any images. A preliminary practice trial was completed with the experimenter to ensure that the participants understood the instructions and the pace of the experimental trials.

Following the completion of the RSVP task, participants completed the Form Y version of the State/Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). The STAI contains a list of 40 statements, where the participant is to answer 1-4 based on how well each statement describes them. The first 20 statements refer to the participant's current anxiety levels (state) and the last 20 statements refer to the participant's general anxiety levels (trait). Each participant received a state anxiety score and trait anxiety score ranging from 20-80, where higher scores suggest higher anxiety. The STAI was collected in order to enable these data to be integrated into a larger project but are not related to the primary purpose of this thesis; thus, they will not be discussed further.

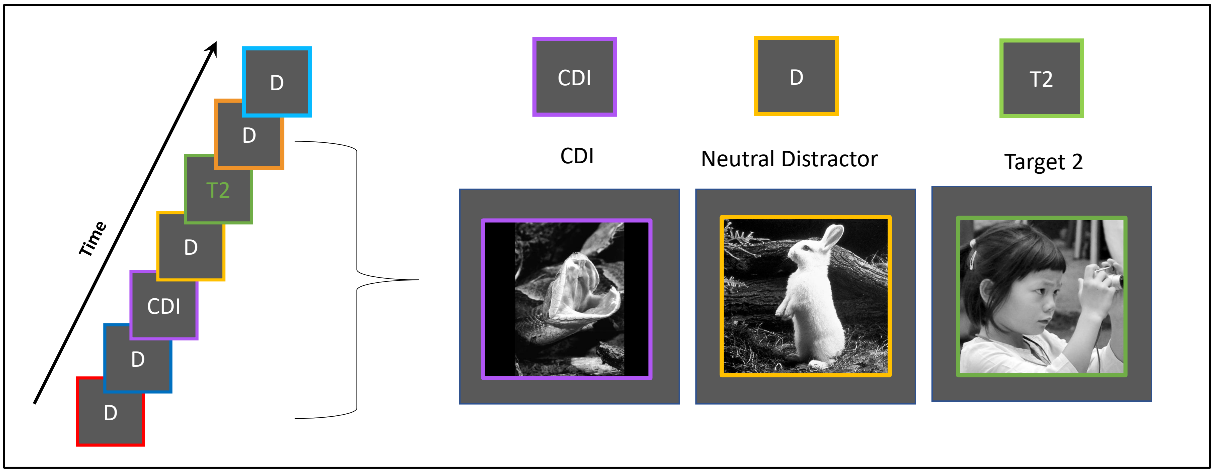

Figure 2: An example of the RSVP task used for the EIB condition. Left: task schematic. Right: Enlarged section of the RSVP stream consisting of an example sequence of an emotional CDI, a neutral distractor and T2 as seen on the computer screen

Stimuli and Materials

The experiment was run using Psychophysics Toolbox suite for MATLAB (Brainard, 1997; Kleiner et al., 2007; Pelli, 1997). Participants were seated at a desk with a computer keyboard approximately 70 cm from a 19-inch Hitachi CM751 cathode-ray tube (CRT) monitor with a refresh rate of 85 Hz. All images, both neutral and CDIs, were selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008). Images were presented in black and white and were centered on the screen. Each image was outlined in a color, where the target was chosen as the greenest green on an approximately equiluminant color wheel. No colors within 60 degrees of that green on the color wheel were used. The remaining 240 degrees of color wheel were divided into 12 increments of 20 degrees, and the 13 colors that separated those 12 increments were used as distractor colors. Each distractor color was used either one or two times on each trial. Thus, the target color (green) and each distractor color appeared equally frequently. This means that there was no bottom-up salience for the target color due to it appearing less frequently than the distractor colors, which is important because the goal of this project is to compare the time courses of purely top-down and bottom-up control of temporal attention, respectively.

Results

All statistical analyses were performed using JASP (JASP Team, 2018). For AB trials, T2 accuracy was defined by correctly reporting T2 in trials where T1 was also accurately reported. For EIB trials, accuracy was defined by correctly reporting the single target (which is here called T2, as it occupies the same ordinal positions in the RSVP stream as T2 in the AB condition). Within-subject performance data were subjected to 7 (Lag 1, Lag 2, Lag 3, Lag 4, Lag 5, Lag 6, Lag 8, Lag 10) x 2 (AB or EIB) repeated-measures analysis of variance (ANOVA). The goal of the current study was to compare the time courses of top-down (AB) and bottom-up (EIB) attention, which was hypothesized in the Current Study section to show a more transient blink for EIB.

When data were subjected to an 7 (Lag 1, Lag 2, Lag 3, Lag 4, Lag 6, Lag 8, Lag 10) x 2 (AB or EIB) ANOVA, they revealed a significant main effect of lag $F(6, 42) = 20.468$, $p < .001$, depicting an overall AB. The ANOVA also showed a main effect for condition $F(1,7) = 51.961$, $p < .001$, meaning that the trial condition had a significant effect. There was also an effect for condition by lag $F(6, 42) = 14.945$, $p < .001$ which indicates an interaction between condition and lag. These results, shown in Figure 3, show that there was a clear AB but failed to demonstrate any EIB effect. Typical AB data shows a decrease in T2 performance from Lag 1 to Lag 2, and then a steady increase up to Lag 6 where performance levels off. Echoing this typical AB effect, our results show the expected effect in the AB condition (blue line in Figure 3). However, the results from the EIB data (red line, Figure 3) instead show steady performance throughout. These results indicate that the AB effect did not occur in the EIB condition and because of this, the present data cannot support any further comparative analysis of the AB and EIB time courses.

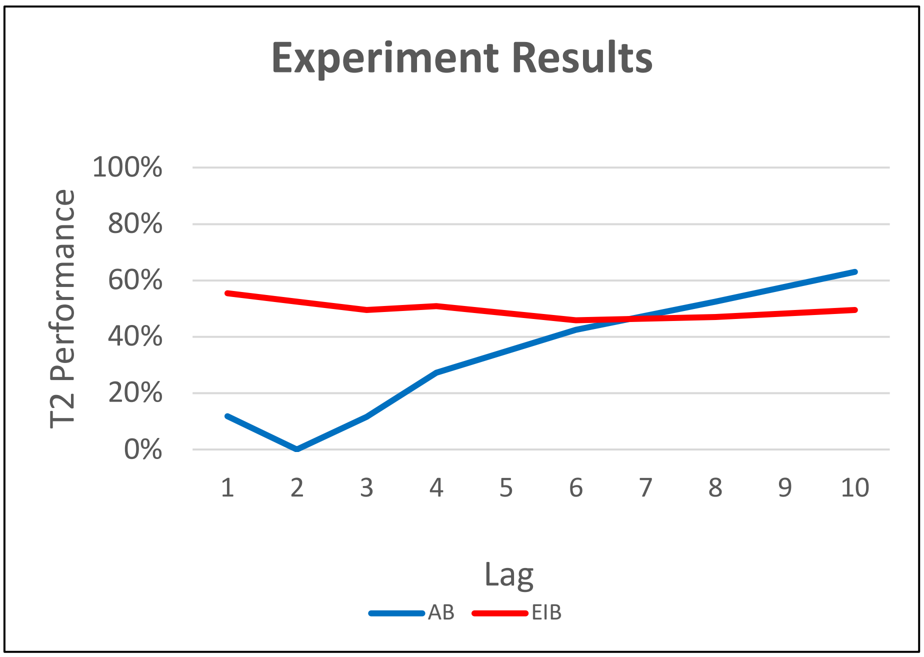

Figure 3: Results of the experiment. Performance calculated as a percent of correctly recalling T2 in trials where T1 was also correctly reported.

Discussion

The goal of this study was to compare the time courses of top-down and bottom-up attention by using the classic AB and the EIB paradigms. In the present study, we attempted to do so by intermixing a classic AB task with an EIB task to examine the time courses of top-down attention (AB) in comparison bottom-up attention (EIB). Previous research on top-down and bottom-up attention using cuing paradigms has shown a fast but transient effect for bottom-up attention, and a slow but durable effect for top-down attention when examining spatial attention (Muller & Rabbitt, 1989). This study aimed to find out if the same differentiation between top-down and bottom-up attention is true for temporal attention. However, the results for the EIB portion of the study did not reveal an AB curve, meaning that participants did not see the emotional images, or, alternatively, that the effect of perceiving an emotional image was longer-lasting than in typical EIB studies but only weakly detrimental to the perception of a subsequent target. Because past studies using similar emotional images showed strong AB-like curves, the former (not perceived) explanation is more plausible. Because participants presumably did not see the emotional images, the AB-like effect that results from EIB studied did not occur and therefore it is difficult to compare the time courses for bottom-up attention from the data collected.

Limitations should be considered when reviewing the results of this study. Firstly, this study used colored frames to specify targets. This method has been used in previous AB and EIB studies, but there is the possibility that participants pay attention to the color rather than the image content which could potentially reduce the effect of the emotional images. This study also used black and white images, which combined with the colored frame, could further reduce emotional impact because the colored frame may jump out more than the image content. The colored frames and the black and white images could have contributed to the fact that there was no EIB effect. Additionally, most EIB studies use categorically distinct distractor items. For example, in Kennedy and Most's (2015) study, the distractor images were categorically homogenous with a categorically distinct distractor item. EIB studies using words as stimuli such as Mathewson et al (2008) and MacLeod et al (2017) had non-target items in the same color (e.g.

white) and distractors in a different color (e.g. red) which would increase the basic bottom-up effect. In this study we chose to use emotional stimuli as bottom-up attention-evoking items, but there are non-emotional ways to evoke bottom-up attention. For example, in Mathewson et al.'s (2008) study, they used arousing but not strongly valenced words (i.e. curse words) as critical distractors instead of using emotionally valenced words. However, most bottom-up attention research uses emotional words and/or images. Another limitation was the study size. This study had only 8 participants due to the difficulty in recruiting participants and an approaching deadline. With a larger sample size, it is possible that there would be more significant or clearer effects.

Overall, the findings of this study are inconclusive. Due to the lack of an EIB effect, there is no way to compare the time courses. We hypothesized that the EIB trials would have a more transient blink, however it is difficult to infer much from the data we collected. Further studies should perhaps slow down the stream even further than 120ms. While this would make the image content more visible, it could run the risk of abolishing the AB effect entirely, as most AB research uses RSVP streams at a rate of approximately 100 ms per item. Another option would be to somewhat replicate the paradigm used by Kennedy and Most (2015) and utilize homogenous streams with categorically salient CDIs. Finally, future studies could instruct participants to identify targets by content rather than the colored border. This way, participants will attend directly to the image content which would increase the chances of their noticing emotional content of CDIs rather than noticing the color of the border. Further studies on this subject would be useful to cognitive literature in order to better understand temporal attention and whether or not the top-down/bottom-up distinctions that occur in spatial attention also occur in temporal attention.

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